

## Spatial and Temporal Distribution of Clouds as Observed by MODIS Onboard the Terra and Aqua Satellites

Michael D. KING,<sup>1</sup> Steven PLATNICK,<sup>1</sup> W. Paul MENZEL,<sup>2</sup> and Steven A.  
ACKERMAN<sup>3</sup>

### ABSTRACT

The Moderate Resolution Imaging Spectroradiometer (MODIS) was developed by NASA and launched onboard the Terra spacecraft on December 18, 1999 and Aqua spacecraft on May 4, 2002. It achieved its final orbit and began Earth observations on February 24, 2000 for Terra and June 24, 2002 for Aqua. A comprehensive set of remote sensing algorithms for cloud masking and the retrieval of cloud physical and optical properties has been developed by members of the MODIS atmosphere science team. The archived products from these algorithms have applications in climate change studies, climate modeling, numerical weather prediction, and fundamental atmospheric research. In addition to an extensive cloud mask, products include cloud-top properties (temperature, pressure, effective emissivity), cloud thermodynamic phase, cloud optical and microphysical parameters (optical thickness, effective particle radius, water path), as well as derived statistics.

Over the last year, extensive improvements and enhancements in the global cloud products have been implemented, and reprocessing of all MODIS data on Terra has commenced since first light in February 2000. In the cloud mask algorithm, the most extensive improvements were in distinguishing clouds at nighttime, including the challenging polar darkness regions of the world. Additional improvements have been made to properly distinguish sunglint from clouds in the tropical ocean regions, and to improve the identification of clouds from snow during daytime in Polar Regions. We will show global monthly mean cloud fraction for both Terra and Aqua, and show how similar the global daytime cloud fraction is from these morning and afternoon orbits, respectively. We will also show the zonal distribution of cloud fraction over land and ocean regions for both Terra and Aqua, and show the time series of global cloud fraction from July 2002 through June 2006.

The cloud top properties algorithm has also undergone changes that led to (i) better assignation of boundary layer clouds to higher heights with effective emissivities less than one (primarily by averaging only cloud radiances in a 5x5 km processing region) and (ii) detection of more high thin cirrus (through a fuller utilization of CO<sub>2</sub> slicing when the cloud signal is greater than the instrument

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<sup>1</sup> NASA Goddard Space Flight Center, Greenbelt, Maryland.

<sup>2</sup> NOAA/NESDIS, University of Wisconsin-Madison, Madison, Wisconsin.

<sup>3</sup> Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison, Madison, Wisconsin.

noise). In addition to changes in the algorithm itself, input radiances have been 'de-striped' before use in Collection 5 processing, to adjust for minor differences in the characteristics of all 10 detectors that are used for each MODIS 1000 m band.

The cloud optical properties algorithm has undergone the greatest number of changes between Collection 4 and Collection 5. These changes have included, but are not limited to, (i) improvements in the cloud thermodynamic phase algorithm, (ii) improvements and substantial changes in the ice cloud light scattering libraries, (iii) new clear-sky restoral algorithm for flagging heavy aerosol and sunglint as cloud-free regions, (iv) vastly improved spectral surface albedo maps, including the spectral albedo of snow by ecosystem, (v) improvements in the effective radius solution logic, and (vi) addition of pixel-level uncertainty estimates for cloud optical thickness, effective radius, and water path, based on uncertainties in calibration, above-cloud water vapor correction, and surface albedo, and taking into consideration the sensitivity of the retrieval algorithm to solar and viewing geometries. In addition, we have (i) eliminated failed retrievals due to detector saturation for large optical thickness (by switching spectral band used in the retrieval), (ii) implemented cloud edge detection and removal, (iii) added a supplementary cloud optical thickness and effective radius algorithm over snow and sea ice surfaces and over the ocean, which enables comparison with the 'standard' retrieval, and (iv) added new multi-layer cloud detection indicators.

We will show not only examples of the impact of these new enhancements on the quality and reliability of the cloud algorithm for selected 5 minute (2000x2330 km) regions, but we will also show their impact on zonal mean cloud optical properties and cloud top properties. Finally, our grid-averaged and time-averaged level-3 MODIS atmosphere product allows us to look at marginal and joint histograms of many cloud properties, and to look at correlations and relations between cloud optical thickness and effective radius, cloud top pressure, and cloud top temperature, and for correlations and relations between cloud effective radius and cloud top pressure and cloud top temperature. Each of these joint histograms is produced for each 1°x1° grid box on the globe and separately for liquid water and ice clouds. Examples from our latest Level-3 algorithm will also be presented.